A Comparison of the Long-Term Hydrological Impacts of Urban Renewal versus Urban Sprawl

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Abstract

Recent concern over environmental and economic impacts of urban sprawl has focused renewed attention on the importance of making full use of existing urban areas. Revitalizing former industrial, commercial, and residential areas often involves changes in land use type or intensity of use. It is important to have the ability to evaluate the long-term hydrological impacts of such changes. These impacts can then be placed within the context of impacts that similar land uses would have if a decision were made to place them in the urban fringe (urban sprawl) rather than in existing urban areas (urban renewal).

In this study, we illustrate how the Long-Term Hydrological Impact Analysis (L-THIA) tool can be used to compare the hydrological impacts of land use change in existing urban areas versus change in the urban fringe. L-THIA is a simple, comparative tool that requires the user to provide information on land use and soil type for existing and future/planned conditions. The tool combines this information with local rainfall data to calculate long-term average annual surface runoff under existing and future/planned conditions. L-THIA analyses can be run directly at our web site for locations throughout the U.S. where the curve number technique is already routinely used (http://danpatch.ecn.purdue.edu/~sprawl/L-THIA). By performing analyses of renewal versus conversion of agricultural land at the urban fringe, it is possible to provide a comparative assessment of impacts. This initial comparison can be helpful in educating the general publicand decision-makers, thereby raising awareness of this element of the set of variables that are considered in land use decisions.

Introduction

Because almost every major North American city had been founded by 1900, the dominant form of urban development during the 20th Century has been growth on the outer edges of existing cities, or just beyond city limits (Orum, 1995). With improvements in transportation and communications, the need for people to be clustered in high-density central areas has decreased (Chinitz, 1991), encouraging decentralization, suburbanization, and sprawl. In the United States, 87% of the population now lives in metropolitan areas and their hinterlands (Angotti, 1995), and steady infilling between urban areas has resulted in the development of megalopolises such as the Philadelphia - Boston - Washington DC - New York urban corridor. Even metropolitan areas which are stagnating or declining in terms of total population are still growing in terms of total built area because of low-density suburban growth (Johnston, 1982).

Decentralization and suburbanization have changed the relative importance of the core areas of cities (Richardson, 1982). Although these central areas were the sites of initial city growth and development, many cities are now faced with the challenge of revitalizing these once vibrant central industrial, commercial, and residential areas that have been in decline in recent decades:. The following quote reflects efforts to slow the tide of migration from urban centers.

"To combat the number of people fleeing [Chicago] for the suburbs, developers have lured middle-class home buyers back with promises of safe neighborhoods and affordable homes. Chicago also leads the nation in converting office and warehouse property into residential space such as condominiums and rental units, often targeted to low- and moderate-income buyers." (Heavens, 1999)

At the same time that city administrations have been coping with the challenges of urban core renewal, suburban and rural communities have become increasingly concerned about the environmental, economic, social, and aesthetic impacts of continued urban growth at the fringes of developed areas (these later concerns are often grouped under the term urban sprawl). Preservation of prime farmland and protection of rural areas have become important concerns, alongside a growing emphasis on combating the impacts of continued sprawl on flooding, groundwater recharge, air pollution, climate, ecology, and habitat fragmentation (Schueler, 1994). Although there is considerable interest3 in revitalizing urban cores, especially if this reduces urban sprawl, to accomplish this requires that the decision-making process for urban and suburban planning include consideration of the environmental as well as the economic aspects of land use.

Land use decisions are highly complex, involving consideration of economics, infrastructure, politics, labor and population dynamics, and the environment. The planning process requires collection and comparison of a wide array of data, usually with the goal of providing a planned solution that meets goals based on sustainable growth in industry and commerce. However, increasing public and political concern over the environmental aspects of urban development has raised the profile of efforts to develop efficient and environmentally sustainable urban environments. The key components of environmentally sound urban development include land use patterns that minimize environmental impacts (Arendt, 1996), efficient automobile and pedestrian traffic, and the use of energy saving and environmentally sound building designs. When attempting to balance economic and environmental concerns, it is important to quantify the differential environmental impacts of alternate land-use scenarios. Objective measures of differential impacts provide a rational basis for decision-making. In addition, they can be used to educate the public and key decision-makers in government and the private sector about the level of environmental benefit that can be gained from alternative land-use decisions.

The aim of the work presented here is to demonstrate the application of an impact assessment tool in evaluating the long-term hydrologic impact of development consistent with urban renewal versus the impact of an identical development located at the urban fringe. Although the general outcome of such a comparison is unlikely to surprise anyone, the advantage of quantifying differential impacts is in providing an objective numeric measure that is much easier to include in decision-making than vague subjective assessments of environmental benefits.

Long-Term Hydrologic Impact Assessment (L-THIA)

In response to concerns from local planners that they had no simple, objective way to assess the impacts of alternate development plans on surface water runoff and groundwater recharge, a Long-Term Hydrologic Impact Assessment tool (L-THIA) has been developed (Harbor, 1994; McClintock et al., 1995; Ogden, 1996; Grove, 1997; Bhaduri et al., 1997; Bhaduri, 1998; Minner, 1998; Minner et al. 1998; Lim et al., 1999; Leitch and Harbor, in press). L-THIA uses readily available data on soils, climate, and land use to estimate long-term surface water runoff. By running the model for current conditions, and then with changed land uses, the user can simulate the potentialimpact of land use change. The method, initially developed as a simple spreadsheet application (Harbor, 1994), is based on the U.S. Department of Agriculture's curve number (CN) method for relating precipitation and runoff as a function of land use and soil type (USDA, 1983, 1986). The CN method was selected because it forms the basis of other commonly used hydrologic models, thus the data required for its use is readily available in most planning settings. Because of the reliance on the CN method, L-THIA applies directly to those areas where the CN method is routinely used. Subsequent development of the L-THIA method has included provision of a Geographic Information System (GIS) version (Grove, 1997), addition of nonpoint source pollution loadings to land uses (Bhaduri, 1998), and development of an Internet--accessible version of the method (Lim et al., 1999).

In the curve number technique, the land use and hydrologic soil type of an area are used to derive a CN value (values typically range from 30 to 98). For any given daily precipitation, surface runoff is then computed from empirically based relationships between rainfall, CN, and runoff. Although most commonly used to estimate runoff for extreme storm events, in L-THIA the CN technique is used to determine daily runoff for a 30-year time series of daily precipitation values.

Average annual runoff is calculated for each CN to provide a measure of long-term average impact, rather than simply impact on isolated extreme storm events. To compare different land use change options, pre-development and post-development average annual runoff can be calculated for each scenario. The L-THIA method is freely available at http://danpatch.ecn.purdue.edu/~sprawl/LTHIA. This site includes information on the technique and its application, as well as access to US climate and soils data necessary to run analyses. Users can submit land use and soil information through a spreadsheet-style interface (Figure 1). Analyses are performed on a server at Purdue University and results are delivered back to the user in the form of tables and graphs.

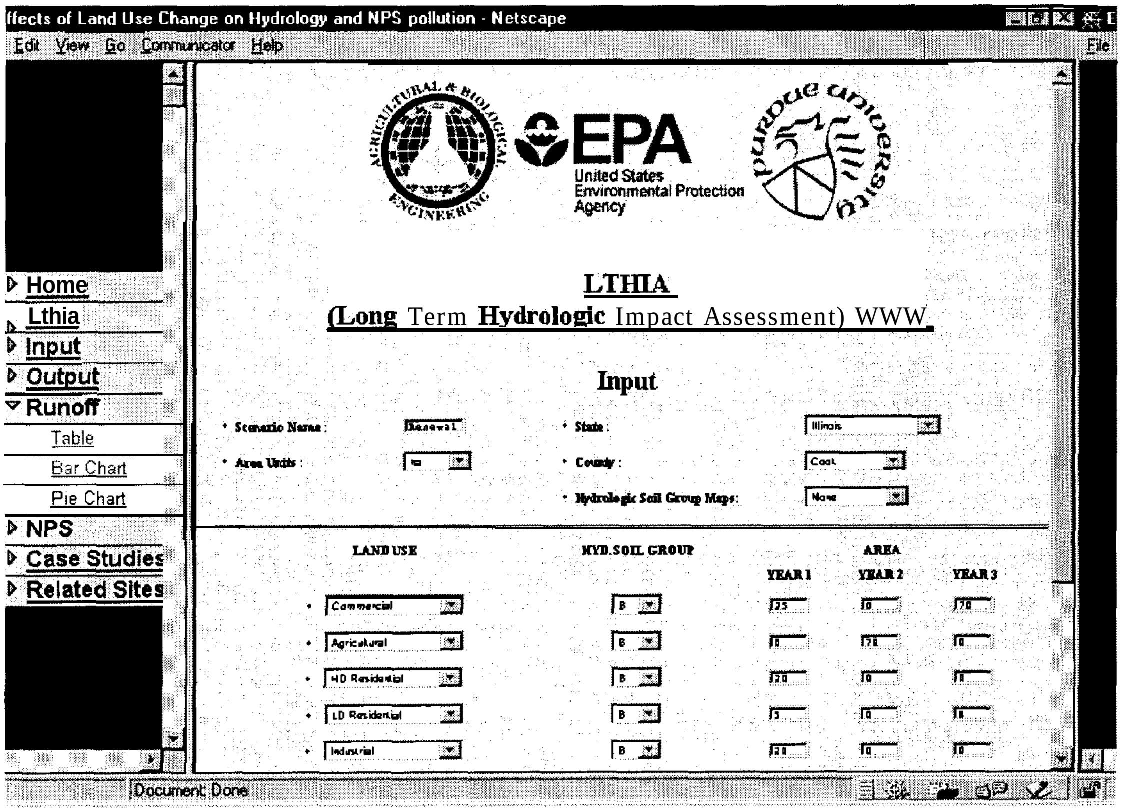

Figure 1. L-THIA WWW Input Screen at http://danpatch.ecn.purdue.edu/~sprawl/LTHIA.

A Comparison of Core Renewal versus Fringe Development

Study Scenario

The L-THIA tool can be used to examine the relative impact of land use change in the form of an urban renewal project; replacing underused or abandoned commercial, residential, and industrial buildings in an urban core region; versus an urban sprawl project; replacing agricultural land at the edge of a city. For the sake of illustration, consider planning a 70 Ha major commercial development with urban core and urban fringe location alternatives. Although the location decision-making process will be driven by economic and infrastructure concerns, also assume that differential environmental impact is important in decision--making, perhaps as a result of political or regulatory pressure. In the context of improving urban environments then, an important question is the extent to which placing this development in an urban core region would have different hydrologic impacts than placing it at the city fringe.

To simulate this situation, consider two possible sites in the Chicago area. The first is in the urban core, and currently consists of a mix of residential, industrial, and commercial properties that are unused or underused (Figure 1). The second possible site is on the urban fringe, and currently is used for agriculture. For simplicity we assume that both sites are on the same type of soil (from a hydrologic perspective), although in a real world example this might not be the case. In each case, we use the L-THIA web tool to analyze how average annual runoff will change if the site is converted to solely commercial use (Figure 1). In the L-THIA input and output, the urban core site is labeled "YEAR 1 ", the urban fringe agricultural site is labeled "YEAR 2" and the commercial land use for both sites is labeled "YEAR 3." The L-THIA web tool uses the "YEAR" designation for different scenarios because analyses are typically for land use changes over time.

Results

For the example described here, placing a commercial development in an urban core region, replacing an existing mix of urban land uses, increases average annual runoff by 58% compared to the initial situation (Table 1 and; Figure 2). Note that the levels of impact given in Table 1 do not depend on the size of the commercial development; the same percent increase applies regardless of area. Runoff increases because land uses with less impervious cover, such as residential, are replaced by commercial land use that has a higher percentage of impervious area. In contrast, for the urban fringe location, replacing agriculture with commercial use increases runoff by 670% (Table 1 and Figure 2), a ten-times greater impact. Runoff increases so dramatically because agricultural use on relatively permeable soil is replaced by very extensive impervious surfaces.

Table 1. Average annual runoff deoths and chanae for commercial development (post-development) in the urban core versus the urban fringe. Results are for the specific example described in the text."

	Pre Development Average Annual Runoff (mm)	Post Development Average Annual Runoff (mm)	Increase in Runoff (%)
Urban Core	81.8	129.3	58
Urban Fringe	16.8	129.3	670

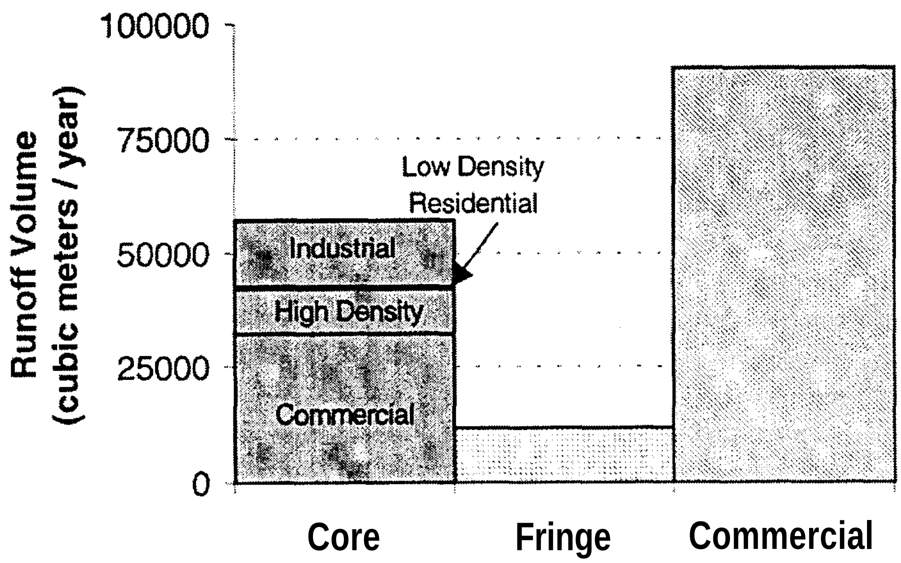

Figure 2. Average annual runoff volumes for commercial development, the urban core mixed-use, and the urban fringe agricultural use. The much larger difference between the fringe location runoff volume and the commercial case indicates that fringe development will have the largest hydologic impact. Note that the runoff volume is simple the average annual runoff depth (Table 1) multiplied by the site area. Results are for the specific example described in the text.

Discussion and Conclusions

The straightforward example presented here indicates that developing a commercial site in an urban core versus and urban fringe location can have a very significant impact on the level of disturbance of the hydrologic regime. For the Chicago example presented here, the urban fringe location produces an approximately ten times larger impact than the urban core location. Clearly, from a solely hydrological standpoint, the urban core location is a better choice than the fringe location. Although this is a hypothetical example, it illustrates the relative ease of use of the L-THIA tool, and more importantly demonstrates an accessible way to provide a quantitative estimate of the relative impacts of different land use decisions. More complex land use mixes and soil types can be run on the L-THIA web tool, either in the spreadsheet version or in a GIS version also available at the web site. Thus, more sophisticated comparative analyses can be performed.

In most cases, an L-THIA analysis provides a result that shows that renewal of existing areas has less hydrologic impact than development of an area with rural use. This is not a surprise, rather the value of the tool is that it provides a context for understanding and considering the magnitude of this difference in the decision-making process. For areas where problems such as groundwater supply and downstream flooding are important, the scale and magnitude of the hydrologic impact can be of considerable importance and can be considered alongside other concerns, such as infrastructure and economic viability. We suggest use of tools such as L-THIA as part of the planning process, to ensure that land use decisions are made after consideration of a full range of concerns, including environmental parameters as well as economic, infrastructure, and political issues.

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